Mecklenburg Cogeneration Facility 204 Co-Gen Drive Clarksville, VA 23927 804/374-6036 *phone* 804/374-6038 *fax*

February 11, 2000

Mr. William Grimley
Emissions Measurement Center
U.S. Environmental Protection Agency
Interstate 40 and Page Road, 4930 Old Page Road
Room Number E-108
Durham, NC 27709
Attn: Electric Utility Steam Generating Unit Mercury Test Program

RE: Mecklenburg Cogeneration Facility Mercury Stack Test Results

Dear Mr. Grimley,

Please find enclosed three (3) copies of the final Mercury Emissions Test Report for the mercury stack testing performed at the Mecklenburg Cogeneration facility during the period October 12 – 13 as required by Part III of the EPA's Mercury ICR effort.

We were unable to get the final report ready for submittal within the requested 90 day period from the test date. Please accept my apologies for the late submittal.

Sincerely,

Glenn T. Burney, Plant Manager
Mecklenburg Cogeneration Facility

cc: Will Poleway (UAE)
Dru Sanders (RMB)
David J. Brown (Virginia DEQ)

DUKE FLUOR DANIEL

Clean Air Engineering

Parkway West Industrial Park, 1601 Parkway View Drive • Pittsburgh, PA 15205 • 412-787-9130
Fax: 412-787-9138
Internet: www.cleanair.com

MERCURY TEST REPORT

Performed for:
MECKLENBURG COGENERATION LP
UNIT 1 APC SYSTEM
CLARKSVILLE, VIRGINIA

Client Reference No: 4735
CAE Project No: 8493
Revision 0: January 27, 2000

To the best of our knowledge, the data presented in this report are accurate and complete.

Submitted by,

Timothy D. Rodak,
Project Manager

Reviewed by,

James E. Wright,
Manager, Eastern Region

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INTRODUCTION

1.1 Summary of Test Program

The U.S. Environmental Protection Agency (EPA) is requiring coal-fired steam generating facilities to provide information that will allow the determination of annual mercury emissions from these units. The information collection effort is being performed in three parts. Part I was used to collect general information about different coal-fired electric utility steam generating units and was completed in January of 1999. Part II involves analysis of coal samples for chlorine and mercury content. Part III of the information collection effort involves collecting mercury emissions data from selected facilities. In response to Part III, the purpose of this test program was to determine mercury emission levels before and after the air pollution control (APC) system of Unit 1 at the Mecklenburg Cogeneration Facility located in Clarksville, Virginia.

The Mecklenburg Cogeneration Facility operates two identical 66 MW coal-fired units and began operation in November of 1992. Each unit has a Foster-Wheeler pulverized coal boiler for production of steam. Pollutant emissions from each unit are controlled through the use of an ABB Flakt dry scrubber and baghouse. Emissions from both units are vented to the atmosphere through a common stack. This test program was designed to measure flue gas mercury levels at the inlet to the dry scrubber and the baghouse outlet of Unit 1.

The testing reported in this document was performed on October 11 through 13, 1999. All sampling procedures were performed in accordance with a Test Plan approved by the EPA.

There were three primary objectives of the test program, including three-dimensional flow characterization, measurement of mercury mass emission rates and removal efficiency, and measurement of mercury and chlorine concentration, composition and heat content of the fuel feed.

1.2 Key Personnel

Table 1-1 outlines the key personnel involved during the field testing portion of the test program.

Table 1-1: Test Program Personnel

Person	Company	Position	Phone Number
Glenn Burney	Mecklenburg Cogeneration	Plant Manager	(804)374-6085 (804)374-6038 - Fax
Jay Berley	Mecklenburg Cogeneration	Test Coordinator	(804)374-6099 (804)374-6038- Fax
Timothy Rodak	Clean Air Engineering	Project Manager	(412)787-9130 (412)787-9138 - Fax
James Wright	Clean Air Engineering	QA/QC Officer	(412)787-9130 (412)787-9138 - Fax

PLANT AND SAMPLING LOCATION DESCRIPTION

2.1 Process Description

The Mecklenburg Cogeneration Facility consists of two identical boilers which operate using a typical pulverized coal steam cycle. Eastern bituminous coal delivered by rail from Pike and Martin counties in Kentucky is pulverized to a fineness of 75% passing through 200 mesh. The coal/air mixture is injected into the lower furnace at 175°F where ignition is initially aided with No. 2 fuel oil. During normal steady state operation coal is the only fuel. The maximum fuel flow is 35 tons/hr per boiler.

The rated boiler temperature and pressure is 950°F and 1625 psia. The boiler exit gas passes through a tubular air heater where the temperature is reduced to approximately 300°F. The gas stream then passes from the boiler building to the Air Pollution Control (APC) system.

A schematic of the process is shown in Figure 2-1.

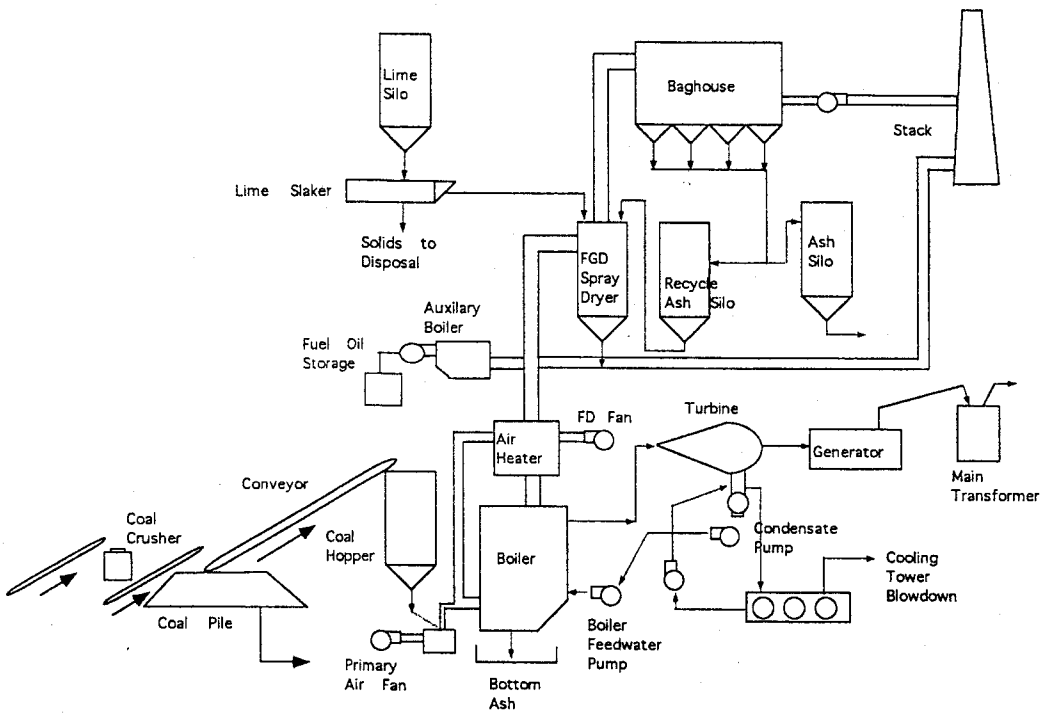


Figure 2-1: Overall Process Schematic

PLANT AND SAMPLING LOCATION DESCRIPTION

2.2 Control Equipment Description

After exiting the boiler building the flue gas enters the dry scrubber. Quicklime is slaked to form a lime slurry which is then added to a water and flyash mixture. This mixture is then sprayed into the top of the scrubber reactor where it directly contacts the dirty gas stream from the boiler. A minimum of 92% of the sulfur dioxide (SO_2) is removed in the scrubber/baghouse. The temperature of the gas stream exiting the scrubber reactor is 160°F.

After passing through the scrubber reactor, the flue gas enters the baghouse where particulate, including the captured sulfur products, is filtered from the gas stream. The clean gas exiting the baghouse is drawn through the outlet duct by an induced draft fan which then discharges the gas into a 275' high stack. Both Unit 1 and Unit 2 discharge flue gas into a common stack.

Mercury testing was performed concurrently at the dry scrubber inlet duct and the baghouse outlet duct of the Unit 1 APC system. In addition, coal samples were obtained from coal feed pipes during mercury testing. A detailed diagram of the Air Pollution Control (APC) system including the location of test points is shown in Figure 2-2.

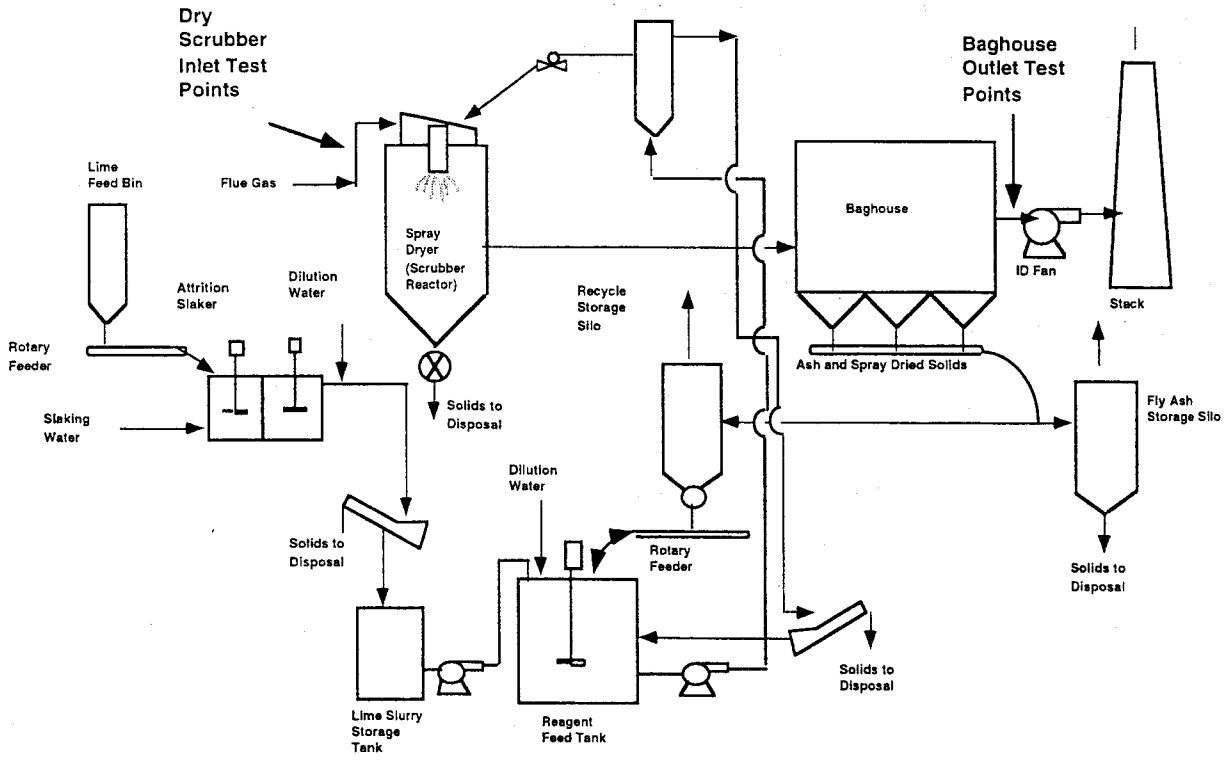


Figure 2-2: Air Pollution Control (APC) System Flow Diagram

2.3 Flue Gas Sampling Locations

Emission testing was performed at the following Unit 1 locations:

- Scrubber Inlet
- Baghouse Outlet

Sampling point locations were determined according to EPA Method 1.

Table 2-1 outlines the sampling point configurations for each test method. Figure 2-4 and Figure 2-6 illustrate the sampling points and orientation of sampling ports for each of the sources tested in the program.

Table 2-1:
Traverse and Sampling Points

Location	Constituent	Method	Run No.	Ports	Points per Port	Minutes per Point	Total Minutes	Figure
Unit 1 Scrubber Inlet	3-D Flow [1]	EPA Method 1	1	7	4	NA	NA	2-4
	Volumetric flow	EPA Method 1-4 [2,3,4]	1-3	7	4	NA	NA	2-4
	Mercury	Ontario Hydro Method	1-3	7	2 [3]	10	140	2-4
Unit 1 Baghouse Outlet	3-D Flow [1]	EPA Method 1	1-4	7	4	NA	NA	2-6
	Mercury	Ontario Hydro Method	1-3	7	4	5	140	2-6

[1] Three-Dimensional flow traverses were performed prior to mercury measurements in order to determine the suitability of flow testing (EPA Method 1, Section 2.5.1) at each sampling location.

[2] Flow measurements at each of the 28 traverse points were made before and after each mercury test run. The average results of pre and post-test measurements were used to determine mercury mass emission rates for each test run.

[3] Only sampling points 3 and 4 were used for mercury measurements to prevent breaking glass sampling components (See Section 2.3.1 of this report for further details).

[4] Moisture measurements were made in conjunction with "Ontario Hydro Method" testing.

PLANT AND SAMPLING LOCATION DESCRIPTION

2.3.1 Scrubber Inlet

Several sampling modifications and considerations were made at the dry scrubber inlet of Unit 1. The sampling location was located in a section of tapering duct approximately 0.6 duct diameters before entering the Unit 1 dry scrubber. Figure 2-3 is shown to illustrate the tapered section of duct located at the scrubber inlet.

An alternative sampling location was not available; therefore, a three-dimensional (3-D) flow traverse using procedures outlined in EPA Method 1 Section 2.5 was performed prior to any mercury measurements to determine the suitability of flow measurement at the scrubber inlet.

In addition to being located in a tapered section, the scrubber inlet location contained internal bracing at the approximate center of the duct making flow traversing difficult. Velocity measurements at traverse points 1 and 2 were recorded after considerable maneuvering of the sample probe past internal bracing and obstructions. Traverse points 1 and 2 could not be sampled using a glass nozzle and liner components at the end of the probe without being broken at each port; therefore, only sample points 3 and 4 were sampled for mercury measurements. A complete discussion of flow measurement considerations is detailed in Section 3.2.1. Figure 2-4 shows the sample points for 3-D flow and mercury testing.

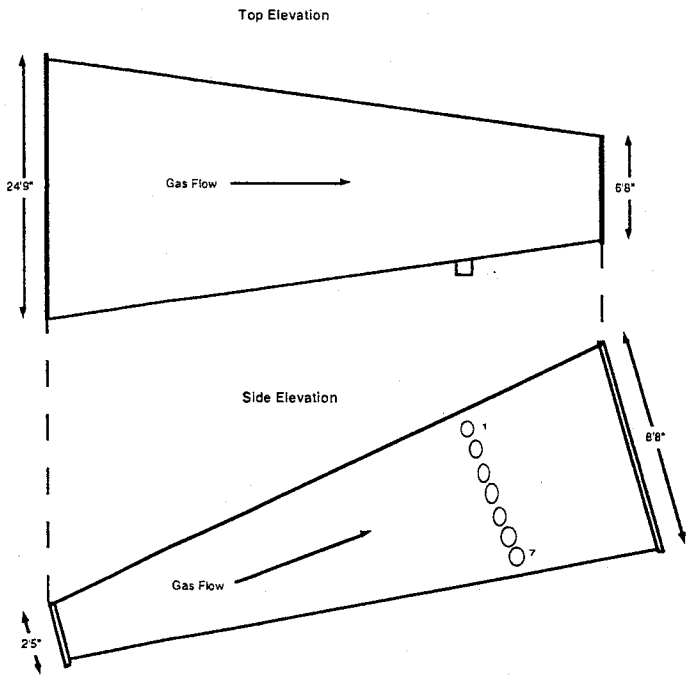
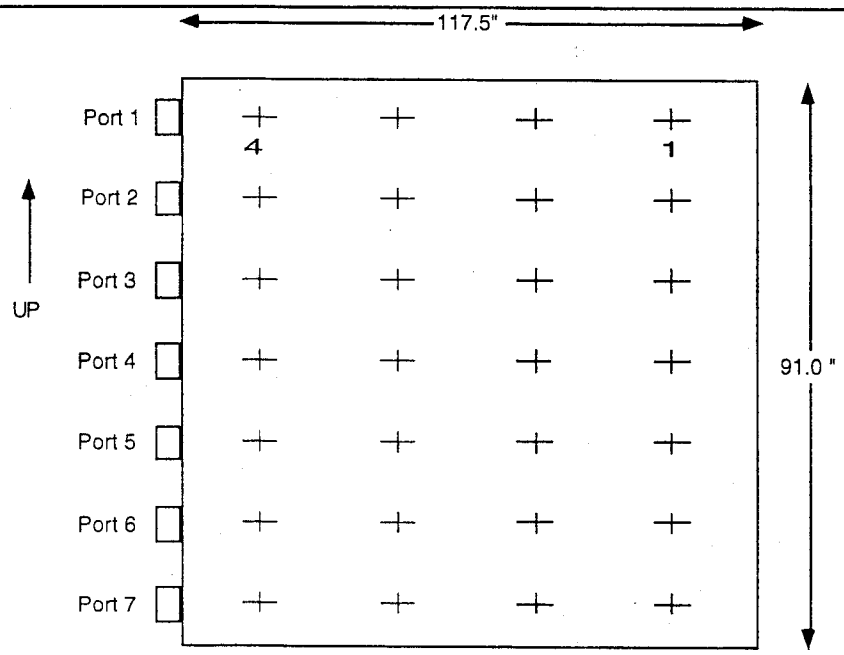


Figure 2-3: Scrubber Inlet Elevation Diagram

PLANT AND SAMPLING LOCATION DESCRIPTION



Sampling Point	Port to Point Distance (in.)
1	102.9
2	73.5
3	44.1
4	14.7

Equivalent Diameter: 102.6 inches

Equivalent Diameters to upstream disturbance: 2.5 Limit: 2.0 minimum
Equivalent Diameters to downstream disturbance: 0.6 Limit: 0.5 minimum

Notes: Sample points 3 and 4 in each port were used for mercury testing

Figure 2-4: Scrubber Inlet Sampling Point Determination (EPA Method 1)

PLANT AND SAMPLING LOCATION DESCRIPTION

2.3.2 Baghouse Outlet

The baghouse outlet sampling location was also located in a section of tapering ductwork. Three-dimensional flow testing was performed at low, mid and high load conditions in order to determine the suitability of the location for flow measurements.

Figure 2-5 is an illustration of the tapering duct at the baghouse outlet location. Figure 2-6 shows the sampling points that were used for 3-D flow and mercury testing.

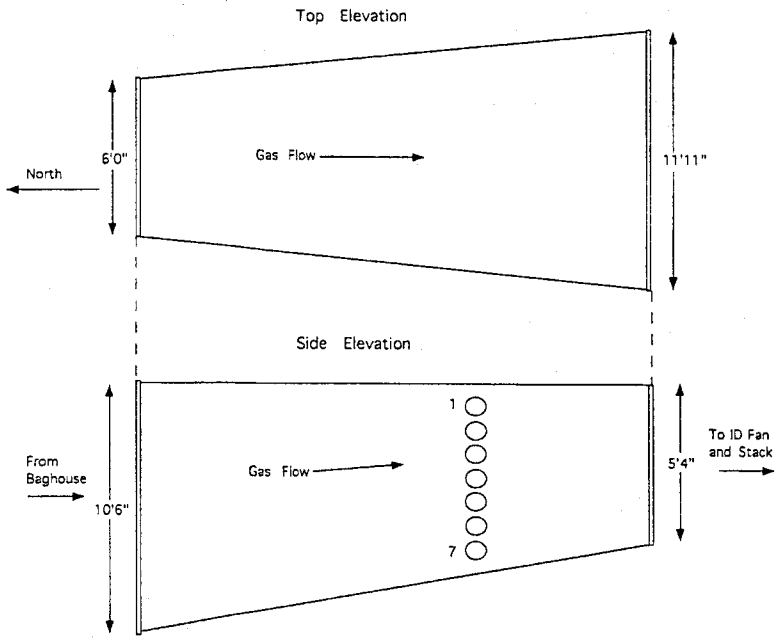
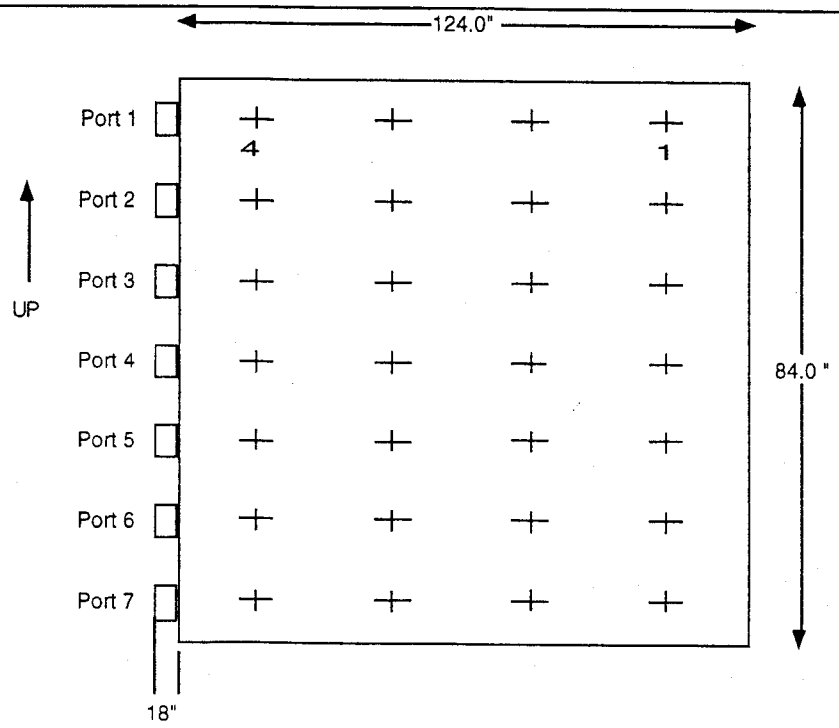


Figure 2-5: Baghouse Outlet Elevation Diagram

PLANT AND SAMPLING LOCATION DESCRIPTION



Sampling Point	Port to Point Distance (in.)
1	108.5
2	77.5
3	46.5
4	15.5

Equivalent Diameter: 100.2 inches

Equivalent Diameters to upstream disturbance: 1.8 Limit: 2.0 minimum
Equivalent Diameters to downstream disturbance: 0.7 Limit: 0.5 minimum

Figure 2-6: Baghouse Outlet Sampling Point Determination (EPA Method 1)

2.4 Process Sampling Locations

In order to characterize the composition of the fuel during testing, coal samples were obtained concurrently with flue gas testing. Coal feeders provide pulverized coal to the burners of each unit. Three grab samples were obtained over equal intervals during each test run. A composite sample was then generated from the three grab samples. Three total samples were analyzed for heat content and composition, including analyses for ash content, moisture, sulfur, mercury and chlorine. The coal analysis was performed by Geochemical Testing located in Somerset, Pennsylvania.

SUMMARY AND DISCUSSION OF TEST RESULTS

3.1 Objectives

The purpose of this test program was to characterize mercury emissions generated from the Unit 1 boiler unit at the Mecklenburg Cogeneration Facility and provide mercury emissions data for use in the regulation of emissions of hazardous air pollutants (HAPs). The program was designed to measure mercury concentrations concurrently at the inlet to the dry scrubber and the outlet of the baghouse which control pollutant emissions from Unit 1.

Specific objectives of the test program included:

- Objective 1: Determine the suitability of the scrubber inlet and the baghouse outlet for volumetric flow measurements.
- Objective 2: Measure mercury emissions and removal efficiencies of the APC system.
- Objective 3: Measure mercury and chlorine concentrations in the coal used for fuel.

Table 3-1 outlines the test matrix for the test program.

Table 3-1: Test Matrix

Date (1999)	Run No. [1]	Test Location	Parameter	Test Method	Run Time
October 11	1	SDA Inlet	Three-Dimensional Flow Analysis	EPA Method 1 of 40 CFR 60 (2.5.1)	15:00-15:45
October 12	1	BH Outlet	Three-Dimensional Flow Analysis - Low	EPA Method 1 of 40 CFR 60 (2.5.1)	8:00-8:39
	2	BH Outlet	- Mid	EPA Method 1 of 40 CFR 60 (2.5.1)	9:30-10:50
	3	BH Outlet	- High	EPA Method 1 of 40 CFR 60 (2.5.1)	12:15-12:52
	1A	SDA Inlet	Volumetric flow	EPA Method 2 of 40 CFR 60	12:44-13:02
	1	SDA Inlet BH Outlet	Mercury	"Ontario Hydro Method" Draft (9/99)	14:55-17:40 14:55-17:39
	1	Unit 1 Coal Feed Pipes	Coal Sampling [2]	ASTM D2234-97A	14:55-17:40
	1B	SDA Inlet	Volumetric flow	EPA Method 2 of 40 CFR 60	18:00-18:15
October 13	4	BH Outlet	Three-Dimensional Flow Analysis - High	EPA Method 1 of 40 CFR 60 (2.5.1)	8:15-9:17
	2A	SDA Inlet	Volumetric flow	EPA Method 2 of 40 CFR 60	8:25-8:41
	2	SDA Inlet BH Outlet	Mercury	"Ontario Hydro Method" Draft (9/99)	9:45-12:25 9:45-12:25
	2	Unit 1 Coal Feed Pipes	Coal Sampling [2]	ASTM D2234-97A	9:45-12:25
	2B/3A	SDA Inlet	Volumetric flow	EPA Method 2 of 40 CFR 60	12:55-13:13
	3	SDA Inlet BH Outlet	Mercury	"Ontario Hydro Method" Draft (9/99)	13:20-15:54 13:20-15:55
	3	Unit 1 Coal Feed Pipes	Coal Sampling [2]	ASTM D2234-97A	13:20-15:55
	3B	SDA Inlet	Volumetric flow	EPA Method 2 of 40 CFR 60	16:10-16:25

[1] "A" and "B" designations refer to "pre-test" and "post-test" velocity traverses, respectively.
[2] Coal samples were analyzed for ash, moisture, sulfur, Btu content, chlorine and mercury.

3.2 Field Test Changes and Problems

3.2.1 Scrubber Inlet - EPA Method 1 Sampling Points

As shown in Figure 2-4, mercury sampling at the scrubber inlet was performed using sample points 3 and 4. Preliminary velocity and three-dimensional flow measurements revealed bracing obstructions inside the duct at the approximate center of the flue gas stream. Metal traversing probes could be maneuvered to points 1 and 2 for each sample port, but with some difficulty. In order to prevent damage to glass sampling components at the end of the mercury sampling probe only points 3 and 4 were sampled during mercury testing.

Flow measurements at the scrubber inlet were performed before and after each mercury sampling run and consisted of complete velocity traverses of all EPA Method 2 traverse points. Average volumetric flow rates of pre- and post-test traverses were used to determine mass flow rates for each test run. Based on acceptable isokinetic sampling rates (100% ± 10%) and the relatively small difference (6.5%) between sampling velocities and those across the entire duct cross section (See Appendix B), it is believed that the mercury measurements at the scrubber inlet are representative of inlet mercury loading to the APC system.

3.2.2 Baghouse Outlet - Three-Dimensional (3-D) Flow Testing

A three-dimensional (3-D) flow analysis was performed at the baghouse outlet at low, mid and high load conditions. Flow results at the low load condition met criteria for acceptable flow testing as outlined in EPA Method 1 Section 2.5. 3-D Flow tests performed at the mid and high load conditions were above the specified limit of 20°. Initial test runs yielded resultant angles of 22.4° and 21.1°, for the mid and high loads, respectively. The standard deviation of the resultant angle measurements was 11.9 and above the acceptable criteria (<10) for the mid load condition, but below the acceptable criteria at the high load condition (5.2).

Since an alternative test site was not available, mercury testing was performed at the baghouse outlet without deviations to EPA Method 2 methodology. A complete discussion of 3-D flow testing results sampling methodology at the baghouse outlet is provided in Section 3.3.1.

SUMMARY AND DISCUSSION OF TEST RESULTS

3.2.3 Scrubber Inlet and Baghouse Outlet - Sample Volumes

Sample volumes obtained during "Ontario Hydro Method" testing were below the minimum volumes outlined in the Test Plan. A sample volume of 70 dry standard cubic feet (dscf) was expected to produce mercury sample concentrations that were above the analytical detection limit. Based on the final analytical results at both the scrubber inlet and baghouse outlet, total mercury sample concentrations were above the in-stack detection limit.

An average sample volume of approximately 64 dry standard cubic feet (dscf) was obtained at the baghouse outlet, or 8.6% below the desired volume. As would be expected based on particulate grain loading, the particle-bound mercury fraction was below the analytical detection limit, but the oxidized and elemental mercury fractions were in excess of this limit in most cases (Only Run 3 oxidized mercury fraction was below the detection limit at <0.03 µg). Baghouse outlet mercury determinations are therefore believed to be representative of actual mercury emissions and were not compromised by the low sample volume.

SUMMARY AND DISCUSSION OF TEST RESULTS

3.3 Field Test Results

3.3.1 Objective 1:
Determine the suitability of the scrubber inlet and the baghouse outlet for volumetric flow measurements.

Representative flow rates were necessary in order to measure mercury mass emission rates and removal efficiency from the Unit 1 APC System. Although the scrubber inlet and the baghouse outlet met EPA Method 1 criteria for duct diameters upstream and downstream, the locations were located in tapered duct sections. Before mercury testing was performed, the resultant gas flow angle was measured using a three-dimensional directional probe (EPA Method 1, Section 2.5).

The results of the 3-D flow traverses are shown in Table 3-2.

Table 3-2: Unit 1 Scrubber Inlet and Baghouse Outlet - 3-D Flow Results

Location	Sampling Method	Load Condition	Pitch Angle	Yaw Angle	Resultant Angle
Unit 1					
Scrubber Inlet	EPA Method 1 (3-D Probe)	High	7.7°	10.0°	13.5°
Baghouse Outlet	EPA Method 1 (3-D Probe)	Low	2.0°	10.8°	11.1°
	EPA Method 1 (3-D Probe)	Mid	17.6°	11.9°	22.4°
	EPA Method 1 (3-D Probe)	High [1]	11.8°	12.0°	19.7°

[1] Angles are the average value from two (2) test runs performed on October 12 and 13, 1999.

Three-Dimensional flow testing was performed at the Unit 1 scrubber inlet on October 11, 1999. The resultant angle measured was 13.5° with a standard deviation of 9.0 and was within the specified limits of ± 20.0° and 10.0 in EPA Method 1.

SUMMARY AND DISCUSSION OF TEST RESULTS

Before beginning mercury testing on October 12, 1999, three-dimensional flow testing was performed at the Unit 1 baghouse outlet. Measurements were made at three (3) load conditions, low, mid and high, corresponding to approximately 23, 47 and 70 Megawatts, respectively. The resultant angle was acceptable at the low load condition at 11.1°, but was in excess of 20° at the mid and high load conditions (22.4 and 21.1). The standard deviation of the resultant angle calculations were 11.9 and 7.6 for the mid and high load condition, respectively. Since the resultant angles obtained were only slightly over the specified limit (<20°) and an alternative test location was not available, mercury testing was begun on October 12, 1999. Mercury test procedures followed the methodology outlined in the "Ontario Hydro Method" and in accordance with the Test Plan.

Before proceeding with mercury test Run 2 at the high load condition, a second three-dimensional flow measurement was performed at the baghouse outlet in order to duplicate the previous flow results under high load conditions. The results of the second three-dimensional test yielded a resultant angle of 18.3° and a standard deviation of 5.2, both within acceptable limits. The average resultant angle of the two test runs was 19.7°, 0.3° below the acceptable limit of 20°. Mercury test Runs 2 and 3 were performed with no modifications to the flow measurement procedure.

A comparison of volumetric flow rates obtained through three-dimensional flow and standard EPA Method 1 through 4 procedures is shown in Table 3-3.

Table 3-3:
Unit 1 Volumetric Flow Comparison (High Load) -
Three-Dimensional Flow vs.
"Ontario Hydro Method" Flow (EPA Method 1-4)

Location Sampling Method	Parameter	Average Results	Percent Difference
Unit 1 Scrubber Inlet			
EPA Method 1 (3D)[1,2]	Volumetric flow rate, actual (acfm)	218,300	
EPA Method 1-4 (S-Type Pitot)[3]	Volumetric flow rate, actual (acfm)	222,100	1.7%
EPA Method 1 (3D)[1,2]	Volumetric flow rate, standard (dscfm)	138,000	
EPA Method 1-4 (S-Type Pitot)[3]	Volumetric flow rate, standard (dscfm)	136,500	-1.1%
Unit 1 Baghouse Outlet			
EPA Method 1 (3D)[1]	Volumetric flow rate, actual (acfm)	200,000	
EPA Method 1-4 (S-Type Pitot)[3]	Volumetric flow rate, actual (acfm)	231,700	13.7%
EPA Method 1 (3D)[1]	Volumetric flow rate, standard (dscfm)	150,800	
EPA Method 1-4 (S-Type Pitot)[3]	Volumetric flow rate, standard (dscfm)	160,700	6.2%

[1] Average oxygen, carbon dioxide and moisture values from "Ontario Hydro Method" mercury testing on October 12 and 13, 1999 were used to determine volumetric flow rates.
[2] Boiler load was increased from a low to high load condition over the period of 3-D flow testing on October 11, 1999. For comparison purposes the volumetric flow values listed are those obtained on ports 5, 6 and 7 while the unit was stable and operating at a high load condition (approx. 70 MW).
[3] Volumetric flow rates were determined in conjunction with "Ontario Hydro Method" mercury testing.

SUMMARY AND DISCUSSION OF TEST RESULTS

Based on the results shown in Table 3-3 the flow rates obtained through standard EPA Methods 1 through 4 are representative of the flow rate at the scrubber inlet under high load conditions.

Comparison of results at the baghouse outlet show a positive bias of 13.7% of the EPA Method 1-4 flow rate to the three-dimensional (3D) flow measurement. Correction of the scrubber inlet flow rate (135,600 dscfm) for dilution air produces an expected flow rate at the baghouse outlet of 139,750 dscfm. The average measured flow rate during mercury testing was 160,700 dscfm. This flow rate represents a 13.0% difference from the expected flow rate (139,750 dscfm) and a 6.2 % difference from the average 3D flow rate (150,700 dscfm) obtained on October 12 and 13, 1999.

The following observations are made from the flow testing at the Unit 1 scrubber inlet and baghouse outlet sampling locations.

1. Based on the available data, flow measurements at the scrubber inlet are representative of the actual flow rate under high load conditions.
2. Cyclonic flow disturbances (i.e. resultant flow angles > 20°) are present at the baghouse outlet at mid and high load conditions; although additional measurements would be needed to confirm actual flow conditions.
3. Standard EPA Method 1 though 4 flow measurements may introduce a positive bias to the actual volumetric flow rate at the baghouse outlet.

SUMMARY AND DISCUSSION OF TEST RESULTS

3.3.2 Objective 2:

Mercury emissions and removal efficiency of the Unit 1 APC system

Mercury mass emission rates and removal efficiency were measured for the Mecklenburg Cogeneration Facility Unit 1 APC system. Simultaneous measurements were made at the scrubber inlet and baghouse outlet under high load conditions. A total of three (3) test runs were performed using the EPA draft "Ontario Hydro Method" designed for mercury determinations at coal-fired utility plants. Results from the test program are shown in Table 3-4 and Table 3-5.

Table 3-4:
Unit 1 Scrubber Inlet - Mercury Results

Run No.		1	2	3	Average
Date (1999)		October 12	October 13	October 13	
Start Time (approx.)		14:55	09:45	13:20	
Stop Time (approx.)		17:40	12:25	15:54	
Gas Conditions					
O_2	Oxygen (dry volume %)	4.4	4.0	4.0	**4.1**
CO_2	Carbon dioxide (dry volume %)	14.8	15.0	15.0	**14.9**
T_s	Temperature (°F)	301	297	297	**298**
B_{wo}	Moisture (volume %)	9.08	9.54	9.81	**9.48**
F_d	Dry Fuel Factor (dscf/10^6Btu)	9,681	9,744	9,665	**9,697**
Volumetric Flow Rate					
Q_s	Actual conditions (acfm)	214,800	233,200	218,400	**222,100**
Q_{stu}	Standard conditions (dscfm)	132,500	143,100	133,850	**136,500**
Particle-bound Mercury					
C	Concentration (µg/dscm)	10.4598	5.3504	6.5195	**7.4432**
C	Concentration at 7% O_2 (µg/dscm)	8.8116	4.4006	5.3622	**6.1915**
C	Concentration at 12% CO_2 (µg/dscm)	8.4809	4.2803	5.2156	**5.9923**
E	Emission rate (grams/sec)	6.54E-04	3.61E-04	4.12E-04	**4.76E-04**
E	Emission rate (lb/hr)	5.19E-03	2.87E-03	3.27E-03	**3.78E-03**
E	Emission rate (lb/10^6Btu)[1]	8.01E-06	4.02E-06	4.86E-06	**5.63E-06**
Oxidized Mercury					
C	Concentration (µg/dscm)	3.1379	3.9785	2.8742	**3.3302**
C	Concentration at 7% O_2 (µg/dscm)	2.6435	3.2723	2.3640	**2.7599**
C	Concentration at 12% CO_2 (µg/dscm)	2.5443	3.1828	2.2993	**2.6755**
E	Emission rate (grams/sec)	1.96E-04	2.69E-04	1.82E-04	**2.15E-04**
E	Emission rate (lb/hr)	1.56E-03	2.13E-03	1.44E-03	**1.71E-03**
E	Emission rate (lb/10^6Btu)[1]	2.40E-06	2.99E-06	2.14E-06	**2.51E-06**
Elemental Mercury					
C	Concentration (µg/dscm)	5.6782	<0.0343	<0.0351	**<1.9158**
C	Concentration at 7% O_2 (µg/dscm)	4.7834	<0.0282	<0.0288	**<1.6135**
C	Concentration at 12% CO_2 (µg/dscm)	4.6039	<0.0274	<0.0280	**<1.5531**
E	Emission rate (grams/sec)	3.55E-04	<2.32E-06	<2.21E-06	**<1.20E-04**
E	Emission rate (lb/hr)	2.82E-03	<1.84E-05	<1.76E-05	**<9.51E-04**
E	Emission rate (lb/10^6Btu)[1]	4.35E-06	<2.58E-08	<2.62E-08	**<1.47E-06**
Total Mercury					
C	Concentration (µg/dscm)	19.2760	9.3289	9.3936	**12.6662**
C	Concentration at 7% O_2 (µg/dscm)	16.2385	7.6729	7.7261	**10.5458**
C	Concentration at 12% CO_2 (µg/dscm)	15.6292	7.4631	7.5149	**10.2024**
E	Emission rate (grams/sec)	1.21E-03	6.30E-04	5.93E-04	**8.10E-04**
E	Emission rate (lb/hr)	9.57E-03	5.00E-03	4.71E-03	**6.43E-03**
E	Emission rate (lb/10^6Btu)[1]	1.48E-05	7.02E-06	7.01E-06	**9.59E-06**

[1] lb/10^6Btu calculated using a dry fuel factor (F_d) calculated from an ultimate coal analysis.

SUMMARY AND DISCUSSION OF TEST RESULTS

Table 3-5:
Unit 1 Baghouse Outlet - Mercury Results

Run No.		1	2	3	Average
Date (1999)		October 12	October 13	October 13	
Start Time (approx.)		14:55	09:45	13:20	
Stop Time (approx.)		17:39	12:25	15:55	
Gas Conditions					
O_2	Oxygen (dry volume %)	4.8	4.4	4.8	4.7
CO_2	Carbon dioxide (dry volume %)	14.4	14.8	14.2	14.5
T_s	Temperature (°F)	168	166	165	166
B_{ws}	Moisture (volume %)	13.15	13.59	14.09	13.61
F_d	Dry Fuel Factor (dscf/10^6Btu)	9,681	9,744	9,665	9,697
Volumetric Flow Rate					
Q_a	Actual conditions (acfm)	229,300	233,900	231,900	231,700
Q_{sd}	Standard conditions (dscfm)	159,800	162,300	160,100	160,700
Particle-bound Mercury					
C	Concentration (µg/dscm)	<0.0055	<0.0054	<0.0055	<0.0055
C	Concentration at 7% O_2 (µg/dscm)	<0.0048	<0.0045	<0.0048	<0.0047
C	Concentration at 12% CO_2 (µg/dscm)	<0.0046	<0.0044	<0.0047	<0.0045
E	Emission rate (grams/sec)	<4.15E-07	<4.12E-07	<4.19E-07	<4.15E-07
E	Emission rate (lb/hr)	<3.30E-06	<3.27E-06	<3.33E-06	<3.30E-06
E	Emission rate (lb/10^6Btu)[1]	<4.32E-09	<4.14E-09	<4.34E-09	<4.27E-09
Oxidized Mercury					
C	Concentration (µg/dscm)	0.0661	0.0645	<0.0166	<0.0491
C	Concentration at 7% O_2 (µg/dscm)	0.0571	0.0544	<0.0144	<0.0419
C	Concentration at 12% CO_2 (µg/dscm)	0.0551	0.0523	<0.0141	<0.0405
E	Emission rate (grams/sec)	4.98E-06	4.94E-06	<1.26E-06	<3.73E-06
E	Emission rate (lb/hr)	3.96E-05	3.92E-05	<9.98E-06	<2.96E-05
E	Emission rate (lb/10^6Btu)[1]	5.19E-08	4.97E-08	<1.30E-08	<3.82E-08
Elemental Mercury					
C	Concentration (µg/dscm)	0.0771	0.2151	0.2052	0.1658
C	Concentration at 7% O_2 (µg/dscm)	0.0666	0.1812	0.1772	0.1417
C	Concentration at 12% CO_2 (µg/dscm)	0.0643	0.1744	0.1734	0.1374
E	Emission rate (grams/sec)	5.82E-06	1.65E-05	1.55E-05	1.26E-05
E	Emission rate (lb/hr)	4.62E-05	1.31E-04	1.23E-04	1.00E-04
E	Emission rate (lb/10^6Btu)[1]	6.05E-08	1.66E-07	1.61E-07	1.29E-07
Total Mercury					
C	Concentration (µg/dscm)	0.1432	0.2797	0.2052	0.2094
C	Concentration at 7% O_2 (µg/dscm)	0.1236	0.2356	0.1772	0.1788
C	Concentration at 12% CO_2 (µg/dscm)	0.1193	0.2268	0.1734	0.1732
E	Emission rate (grams/sec)	1.08E-05	2.14E-05	1.55E-05	1.59E-05
E	Emission rate (lb/hr)	8.57E-05	1.70E-04	1.23E-04	1.26E-04
E	Emission rate (lb/10^6Btu)[1]	1.12E-07	2.15E-07	1.61E-07	1.63E-07
RE	Removal Efficiency	99.1	96.6	97.4	97.7

[1] lb/10^6Btu calculated using a dry fuel factor (F_d) calculated from an ultimate coal analysis.

Observations from mass emission rate and removal efficiency testing are:

1. The mercury mass emission rate measured at the outlet of the Unit 1 APC system was 1.26×10^{-4} lb/hr. This mass emission rate corresponds to a mass removal efficiency of 97.7% based on measured inlet mercury loading.
2. Mercury mass emission rates at the baghouse outlet may have a positive bias based on measured EPA Method 1 through 4 flow rates. Consequently, mercury removal efficiency may have a small negative bias (<0.1%).

SUMMARY AND DISCUSSION OF TEST RESULTS

3.3.3 Objective 3:
Mercury and Chlorine concentrations - Coal Analysis

During mercury testing, coal fuel samples were obtained at the coal feed pipes of Unit 1. These samples were analyzed for mercury and chlorine content. In addition, short proximate and ultimate analyses were performed in order to determine the composition and heat content of the fuel burned. The results from all coal analyses are shown in Table 3-6.

Table 3-6:
Unit 1 Coal Feed Pipes - Coal Analysis Results

Run No.	1	2	3	Average
Date (1999)	October 12	October 13	October 13	
Start Time (approx.)	14:55	09:45	13:20	
Stop Time (approx.)	17:40	12:25	15:55	
Process Conditions [1]				
Total Coal Flow(Klbs/hr)	58.6	61.1	60.5	**60.1**
Proximate Analysis				
Moisture (percent)	5.43	5.64	7.12	**6.06**
Ash (percent)	6.59	7.3	7.15	**7.01**
Ultimate Analysis				
Carbon (percent)	73.56	72.75	71.28	**72.53**
Hydrogen (percent)	5.63	5.64	5.66	**5.64**
Sulfur (percent)	1.19	1.46	1.28	**1.31**
Nitrogen (percent)	1.39	1.38	1.35	**1.37**
Oxygen (percent)	11.64	11.47	13.28	**12.13**
Heating value (Btu/lb)	13,279	13,094	12,879	**13,084**
Dry F factor (dscf/10^6Btu)	9,681	9,744	9,665	**9,697**
Chlorine				
Concentration (mg/Kg, dry)	1,901	1,852	1,925	**1,893**
Mercury				
Concentration (mg/Kg, dry)	0.09	0.11	0.09	**0.10**
APC System Inlet loading (lb/hr)	4.99E-03	6.34E-03	5.06E-03	**5.46E-03**

[1] A complete listing of all process data is included in Appendix Section F.

The APC system inlet mercury loading obtained through a coal fuel analysis (5.46×10^{-3} lb/hr) is consistent with the results obtained through flue gas sampling (6.43×10^{-3} lb/hr); a 15.1% difference. All other parameters in the coal analyses were within expected ranges for bituminous coal.

4. SAMPLING AND ANALYTICAL PROCEDURES

4.1 Test Methods

4.1.1 Gas Flow Distribution Using A Directional Probe

A three dimensional gas flow characterization was performed at the scrubber inlet and baghouse outlet locations in accordance with the Alternative Measurement Site Selection procedure specified in Section 2.5 of EPA Method 1.

Both the standard and the Stauscheibe (S-type) pitot tubes measure gas flow as a one-space vector. An alternative method for measuring gas flow through ducts is with a directional 3-D probe. The directional probe measures gas flow as a three-space vector. The actual velocity vector determined is a three-space vector in a spherical-coordinate system. In any spherical-coordinate system, there is a polar plane and an axis perpendicular to the polar plane. The spherical-coordinate representation of a given vector from the origin involves a magnitude (V) and two angles, q and f. The name "spherical-coordinates" comes from the result of graphing the magnitude (V) as a constant and q and f as variables.

Both the pitch and yaw angles are measured from a line passing through the traverse point and parallel to the duct axis. The pitch angle is the angle of the gas flow component in the plane that includes the traverse line (the probe) and is parallel to the duct axis. The yaw angle is the angle of the gas flow component in the plane perpendicular to the traverse line (the probe) at the traverse point and is measured from the line passing through the traverse point and parallel to the duct axis.

The three-dimensional probe has five pressure taps in the tip. A centrally located hole, P1, measures the stagnation pressure while two lateral holes, P2 and P3, measure the static pressure. The yaw angle is determined by rotating the probe until the difference between the two lateral holes is zero (P2-P3=0) as read on a manometer. The yaw angle of flow is then indicated by a protractor attached to the probe. After determining the yaw angle, a switch is thrown which combines the two static pressure taps and the velocity pressure is measured as P_1-(P_2+P_3) on a manometer. At this time, a pitch angle pressure differential is determined using the pressure taps, (P4 and P5) above and below the stagnation pressure hole, (P1).

SAMPLING AND ANALYTICAL PROCEDURES

A resultant angle (α) and the standard deviation (S_p) were determined from the recorded three dimensional flow data at the scrubber inlet and baghouse outlet. Testing was performed at the scrubber inlet on October 11, 1999 at a mid to high load transition condition (45-70 MW).

Three 3-D test runs were performed at the baghouse outlet on October 12, 1999 at low, mid and high load conditions (25, 48, 70 MW, respectively). Since the resultant angle measured at the high load condition (21.1°) was in excess of the 20° specification in EPA Method 1, Section 2.5, an additional test run was performed on October 13, 1999. The results of this test run produced a resultant angle of 18.3°. The average of the two traverses yield an average resultant angle of 19.7°.

4.1.2 Velocity And Volumetric Flow Rate

EPA Method 2 was used in conjunction with the Ontario Hydro Method to determine the gas velocity and flow rate. Figure 4-1 includes the components of the EPA Method 2 sampling apparatus.

Each set of velocity determinations included the measurement of gas velocity pressure and gas temperature at each of the EPA Method 1 traverse points. The velocity pressures were measured with a Type S pitot tube. Gas temperature measurements were made using a Type K thermocouple and digital pyrometer.

4.1.3 Gas Composition And Molecular Weight

In order to determine the oxygen (O_2) concentration, carbon dioxide (CO_2) concentration and gas molecular weight, a time-integrated sample of the gas was obtained and analyzed in accordance with EPA Method 3B. The gas samples were collected into vinyl sample bags during mercury testing. The contents of the bags were analyzed for O_2 and CO_2 concentrations using an Orsat gas analyzer.

4.1.4 Moisture Content

The flue gas moisture content was determined in accordance with EPA Method 4, in conjunction with the Ontario Hydro Method. Figure 4-1 includes the components of the EPA Method 4 sampling apparatus. The gas moisture was determined by quantitatively condensing the water in chilled impingers. The amount of moisture condensed was determined gravimetrically. A dry gas meter was used to measure the volume of gas sampled. The amount of water condensed and the volume of gas sampled were used to calculate the gas moisture content in accordance with EPA Method 4.

SAMPLING AND ANALYTICAL PROCEDURES

4.1.5 Speciated Mercury Emissions - Ontario Hydro Method

The "Standard Test Method for Elemental, Oxidized, Particle-Bound and Total Mercury in Flue gas Generated from Coal-Fired Stationary Sources (Ontario Hydro Method)" was used to measure the flue gas mercury concentrations. This method applies to the determination of elemental, oxidized, particle-bound, and total mercury emissions from coal-fired stationary sources.

The following definitions apply to each sample fraction:

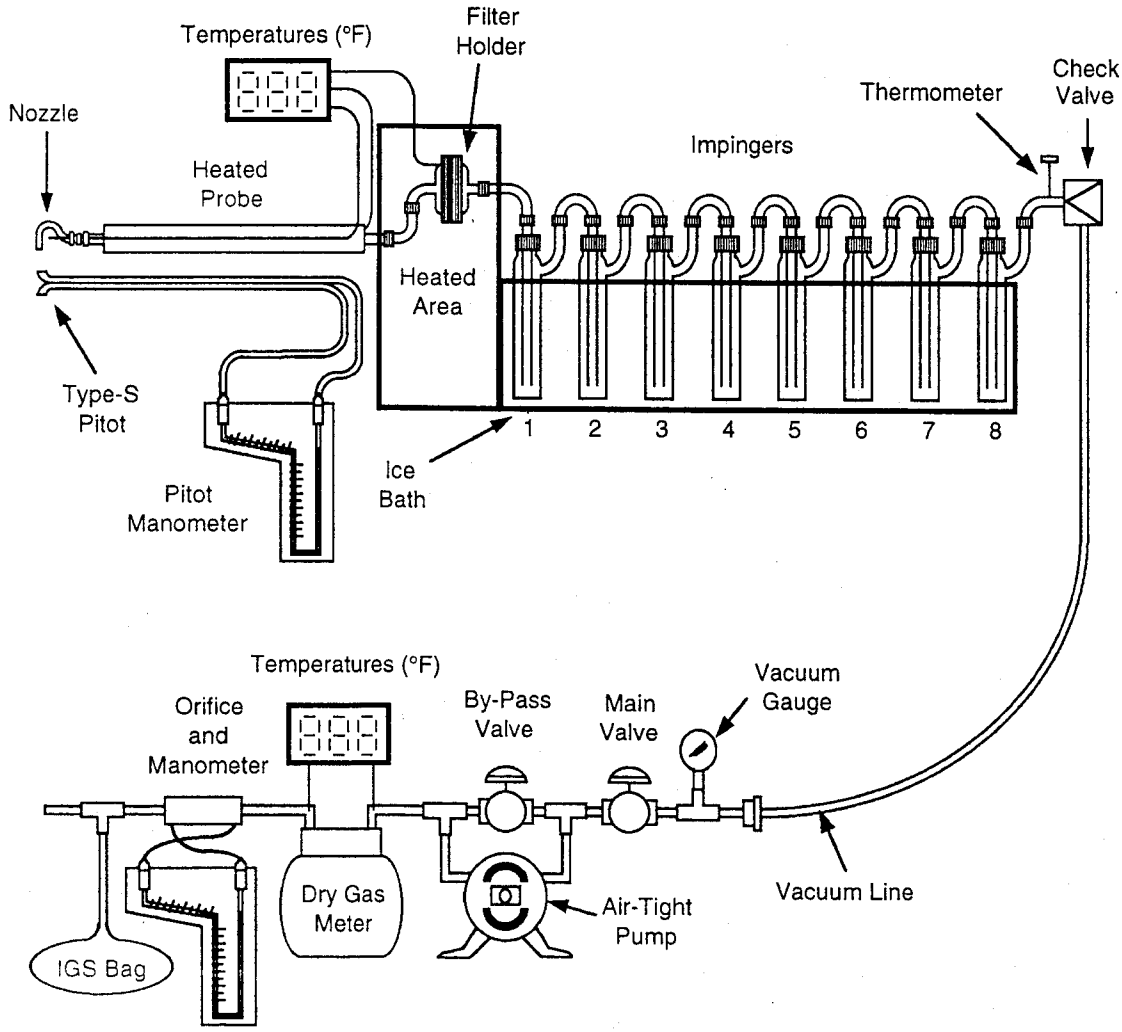
- Elemental Mercury (Hg^0) - Mercury collected in acidified peroxide and potassium permanganate impinger solutions,
- Oxidized Mercury (Hg^{2+}) - Mercury collected in aqueous potassium chloride impinger solution,
- Particle-Bound Mercury (Hg) - Mercury associated with the particulate matter collected in the front-half of the sampling train.
- Total Mercury - The summation of the elemental, oxidized and particle-bound mercury fractions.

Figure 4-1 illustrates the Ontario Hydro Method sampling train which was used at the scrubber inlet and baghouse outlet locations. The sampling apparatus contained a glass-lined temperature-controlled probe equipped with a pitot tube (for measuring stack flow rate) and a sharp-edged glass button-hook nozzle. The exit of the probe was connected to a high efficiency quartz fiber filter (Pallflex 2500QAT-UP) supported in a glass filter holder inside an oven. The exit of the filter holder connected directly to a series of eight full size impingers. The probe and filter exit gas stream temperatures were maintained at a minimum of 149°C (300°F) and within 15°C (59°F) of the flue gas temperature at the scrubber inlet. Probe and filter temperatures were maintained at approximately 125°C (248°F) at the baghouse outlet.

The first three impingers of the sampling train each contained 100 milliliters of 1 Normal potassium chloride solution . The fourth impinger contained 100 milliliters of 5% nitric acid/10% hydrogen peroxide solution. The fifth, sixth and seventh impingers each contained 100 milliliters of 4% potassium permanganate/10% sulfuric acid solution. The eighth impinger contained 300 grams of silica gel. All of the impingers were maintained at a temperature below 68°F for the duration of each test. The third and seventh impingers had restricted tips.

Sample test runs were 140 minutes in duration. The entire sampling apparatus was leak-checked before and after each test run. Sampling was performed at an isokinetic rate greater than 90% and less than 110%.

SAMPLING AND ANALYTICAL PROCEDURES



Ontario Hydro Sample Train

Impinger Contents
1) 100 ml 1 M KCl
2) 100 ml 1 M KCl
3) 100 ml 1 M KCl
4) 100 ml 5% HNO_3/10% H_2O_2
5) 100 ml 4% $KMnO_4$/10% H_2SO_4
6) 100 ml 4% $KMnO_4$/10% H_2SO_4
7) 100 ml 4% $KMnO_4$/10% H_2SO_4
8) 300 g silica gel

Figure 4-1: Speciated Mercury Sampling Apparatus (Ontario Hydro Method)

SAMPLING AND ANALYTICAL PROCEDURES

At the conclusion of each test run, the probe and nozzle were brushed and rinsed with 0.1 Normal nitric acid to remove any particulate matter. These rinses were collected into glass sample containers. The quartz fiber filter was recovered and placed into the original filter container. The volume of liquid collected in each of the impingers was quantified.

Recovery of the first three impingers involved first adding 4% potassium permanganate/10% sulfuric acid solution to the liquid from the first three impingers until a purple color remained. The resulting liquid was transferred to a leak-free amber glass storage container. The back-half of the filter housing, the first three impingers, and all connecting glassware were quantitatively rinsed with 0.1 Normal nitric acid which was then added to the storage container. Any remaining impinger stains were removed using hydroxylamine sulfate solution and added to the sample container.

Liquid collected in the fourth impinger was transferred to a separate amber glass container, and quantitatively rinsed into the container with 0.1 Normal nitric acid.

The contents of impingers 5, 6 and 7 were collected into an amber glass container. Impingers 5, 6 and 7 and the connecting glassware were then rinsed with 0.1 Normal nitric acid. These rinses were collected in the glass container. Residual potassium permanganate retained by the impingers was removed using hydroxylamine sulfate solution.

All containers were sealed, labeled and liquid levels marked prior to transport to the laboratory.

SAMPLING AND ANALYTICAL PROCEDURES

A flow diagram for the recovery procedure of Ontario Hydro Mercury sample train is shown in Figure 4-2

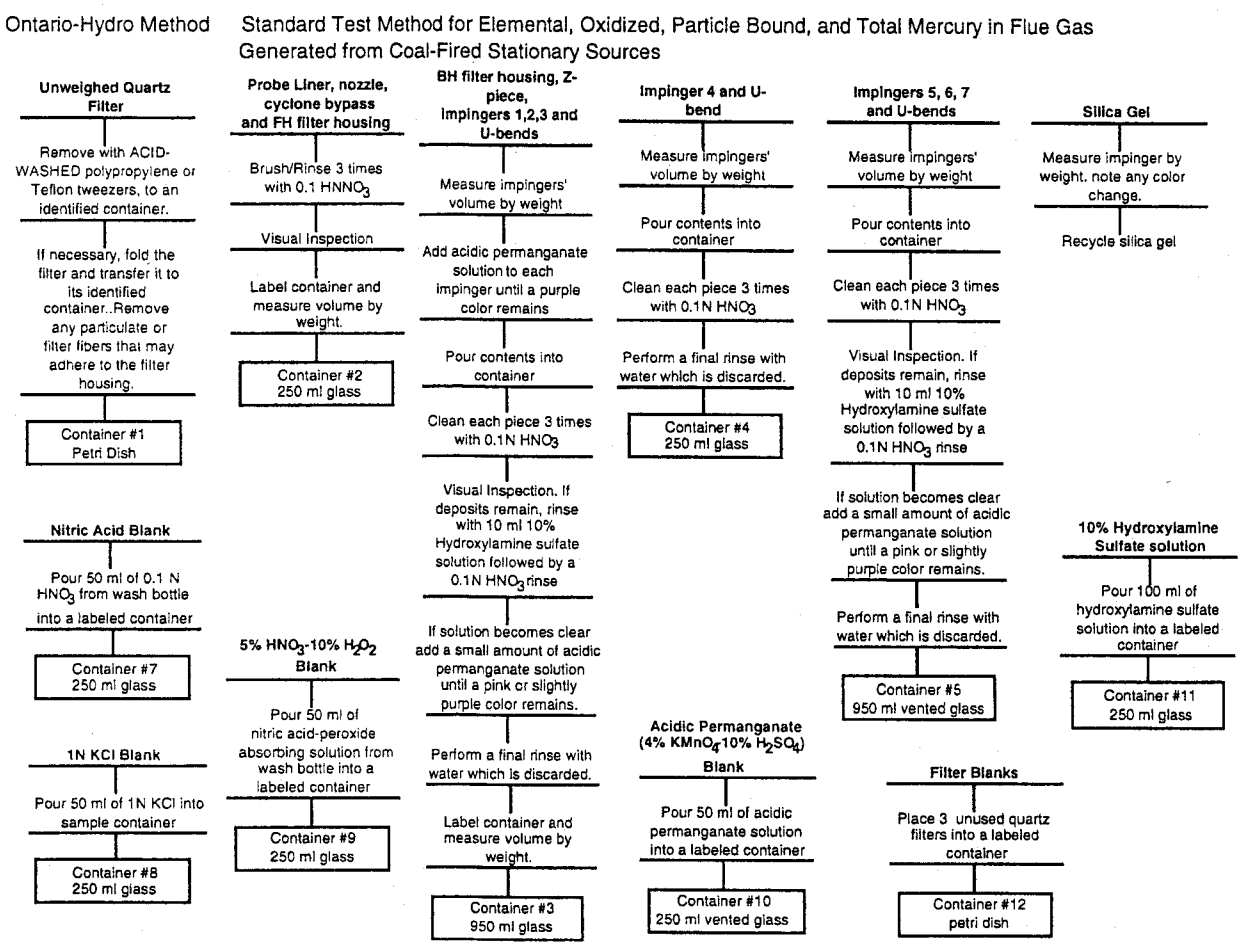


Figure 4-2: Ontario Hydro Method - Field Recovery Procedure

SAMPLING AND ANALYTICAL PROCEDURES

The filters and front half nitric acid rinses were digested and analyzed for mercury, which can be considered as particle-bound mercury. The samples obtained from impingers 1, 2 and 3 were analyzed and the results considered oxidized mercury (Hg^{2+}). The samples from impingers 4, 5, 6 and 7 were analyzed separately and the results considered as elemental mercury (Hg^{0}) as outlined in the Ontario Hydro Method. All of the digested samples were analyzed through cold vapor atomic absorption spectroscopy (CVAAS) by Philip Analytical Services of Burlington, Ontario, Canada. Figure 4-3 outlines the analytical procedure for the final analysis.

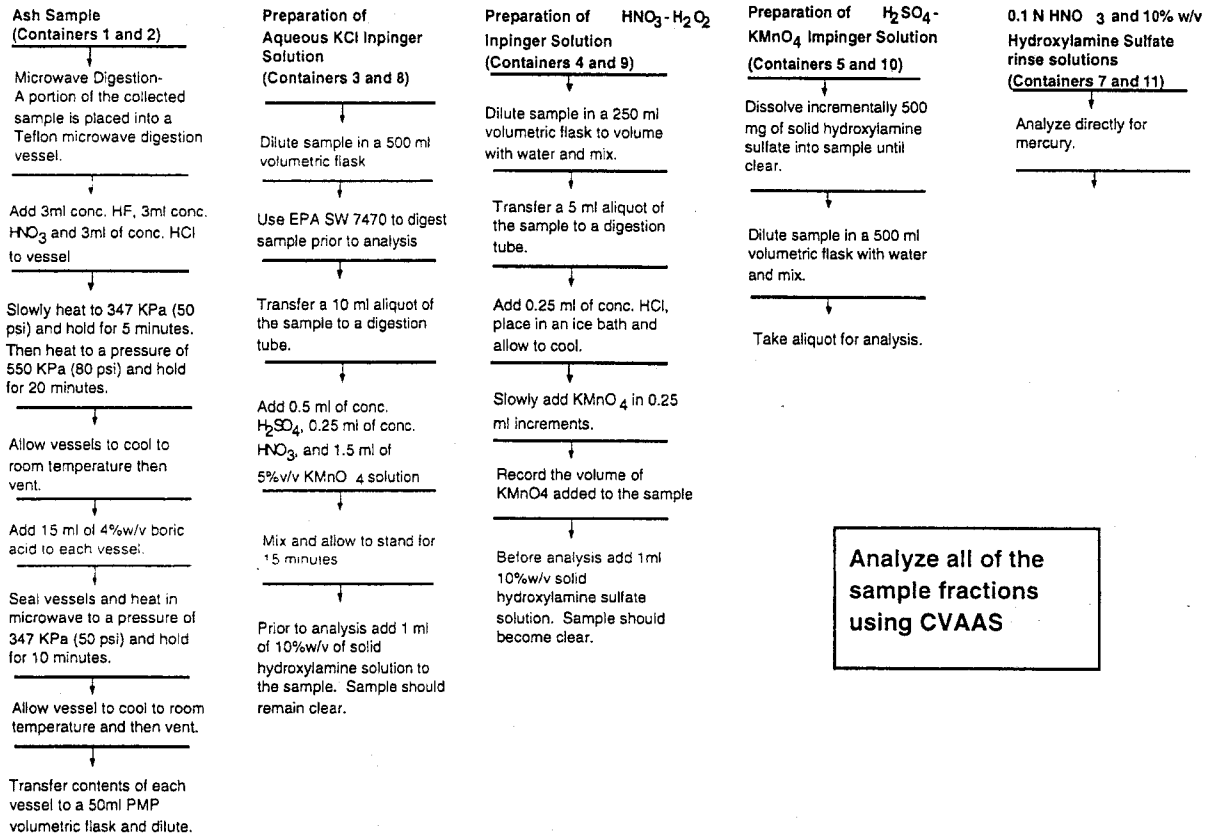


Figure 4-3: Ontario Hydro Method - Analytical Procedure

SAMPLING AND ANALYTICAL PROCEDURES

4.1.6 Coal Sampling

Coal samples were obtained at the coal pipe feeders of Unit 1 and were representative of the fuel burned during each mercury test run. These samples were collected and analyzed using the ASTM methods listed in Table 4-1.

Table 4-1:
Summary of Coal Sampling and Analytical Procedures

ASTM Method	
D2234-97A	"Standard Practice for Collection of a Gross Sample of Coal"
D2013-86	"Standard Method of Preparing Coal Samples for Analysis"
D3172	"Standard Test Methods for Proximate Analysis of the Analysis Sample of Coal and Coke by Instrumental Procedures"
	a)Moisture
	b)Ash
D3176-89	"Standard Test Methods for Ultimate Analysis of the Analysis Sample of Coal and Coke by Instrumental Procedures"
D5373	a)Hydrogen
D5373	b)Carbon
D5373	c)Nitrogen
D4239	d)Sulfur
D3176	e)Oxygen
D3174	e)Ash
D3684-94	"Standard Test Methods for Mercury Analysis in Coal"
D2361-95	"Standard Test Method for Chlorine in Coal"

4.1.7 Process Operating Conditions

The following process operating data was obtained during each test run. All parameters were recorded on the station data logging system and are included in the Appendix Section G.

- Total coal flow
- Individual coal feeder flow
- Steam flow
- Boiler load (Megawatts)
- Unit export steam flow
- FD fan inlet air temperature
- Air heater inlet temperature
- Scrubber inlet temperature
- Scrubber slurry flow
- Scrubber outlet temperature
- Baghouse differential pressure

QA/QC ACTIVITIES

5.1 QA/QC Problems

There were no QA/QC problems with either the field sampling or lab analysis portions of the test program.

5.2 QA Audits

Quality control (QC) procedures consistent with EPA guidelines were followed during all emissions testing. The following sections outline the results of both field and post-test QC measurements.

5.2.1 QC Procedures for Velocity/Volumetric Flow Rate Determination

The following QC procedures were performed for velocity and volumetric flow rate determinations at both sampling locations

- Pre-test verification of Type-S and 3-D probe tips calibrations was performed. Calibration sheets are included in the Appendix.
- Post-test visible inspection of the Type-S and 3-D probe tips showed no damage affecting calibration.
- Both legs of the pitot tube were leak-checked before and after each sampling run.
- The number and location of the sampling traverse points followed EPA Method 1 guidelines with the following exceptions:
  1. Three-Dimensional flow traverses were performed using 28 total points (4 points per port).
  2. Ontario Hydro Method mercury testing at the scrubber inlet was performed using points 3 and 4 in each port due to obstructions at the center of the duct. (See Section 2.3 for discussion).

5.2.2 QC Procedures for Molecular Weight Determination

Gas samples were collected during mercury testing using the integrated sampling technique specified in EPA Method 3B and analyzed for oxygen and carbon dioxide concentrations. The following QC checks were performed daily and within specified limits.

- Orsat apparatus leak check
- Ambient air oxygen measurement
- Comparison of resultant Fo factor with published value (Bituminous coal)

QA/QC ACTIVITIES

5.2.3 QC Procedures for Moisture Determination

The moisture content of the gas stream was determined using the technique specified in EPA Method 4 in conjunction with Ontario Hydro Method mercury testing. The following internal checks were performed and met EPA Method 4 guidelines.

- Impingers were weighed to the nearest 0.1 gram before and after sampling.
- Field impinger weight sheets were checked for accuracy before inputting data into standard mercury data sheets.
- Ice was maintained in the ice bath during each run.
- The exit gas temperature from the last impinger remained below 68°F throughout all test runs.

5.2.4 QC Procedures for Mercury Sampling

The following quality control procedures were followed during Ontario Hydro Method mercury sampling:

- All pre and post-test sampling train leak checks were within acceptable limits.

During Each Test Run:

- Pitot tubes were oriented parallel to the expected direction of flow. (See Section 2.3 for a complete discussion of pitot tube orientation during mercury sampling.
- Sampling trains were leak-checked periodically during test runs. All leak checks were within acceptable limits. Gas volume drawn through the sampling system during leak checks was subtracted from the total sample volume.
- Sample filters were maintained at the specified temperatures. Filter temperature for the scrubber inlet sampling apparatus was maintained at the approximate flue gas temperature.
- An ice bath was maintained in the impoinger apparatus during all testing.
- Readings of the dry gas meter orifice pressure drop, temperature and vacuum were made at 5 minute intervals during testing.
- Isokinetic sampling, within ±10 percent of the measured flue gas velocity, was maintained for all sample runs.

5.2.5 QC Procedures for Calibration

Calibration QC procedures were followed for all sampling equipment used during the test program. Complete calibration documentation is provided in Appendix Section C.

QA/QC ACTIVITIES

5.2.6 QC Laboratory Procedures and Equipment

The following laboratory QC procedures were used in the field and in the analytical laboratory.

Field Sampling Locations and Laboratory:

- Field Blanks were assembled at each sampling location and recovered. Field blanks were analyzed using the same procedures as the test runs.
- Glass sample containers with Teflon caps were used for all Ontario Hydro Method samples.
- Mercury samples were shipped to the off-site analytical laboratory immediately following field testing.
- Samples were preserved using potassium permanganate and hydroxylamine sulfate solution in accordance with Ontario Hydro Method procedures.

Analytical Laboratory

- All samples were received intact at the laboratory.
- Sample fractions were analyzed within the required hold time of 45 days, with the exception of the filter and rinse fractions. These samples were analyzed within 51 days of collection, or 2 days after the specified hold time. Results from these fractions should still provide acceptable elemental particle-bound Hg concentrations since Hg can exist without significant degradation in a stable solid matrix such as flyash.
- Blank spike recoveries were acceptable.
- Duplicate analyses were performed for Test Run 1.
- Reagent blanks were analyzed.